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(73) Proprietor: **E.I. DU PONT DE NEMOURS AND COMPANY**
1007 Market Street
Wilmington Delaware 19898 (US)

(72) Inventor: **Riley, Clifford**
Terracotta Wellhouse Lane
Burgess Hill Sussex (GB)

(74) Representative: **Abrams, Michael John et al**
HASELTINE LAKE & CO. Hazlitt House 28
Southampton Buildings Chancery Lane
London WC2A 1AT (GB)

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Description

This invention relates to the analysis of liquid samples which are carried along a flow channel by a carrier liquid. The method and apparatus of the invention are particularly well suited for use in the automatic analysis of samples of clinical interest, but are also well suited for use in the automatic analysis of agricultural, pharmaceutical and industrial samples.

Various types of analytical apparatus are known. One type of apparatus is known as a discrete analyser, and in this apparatus a sample is placed in an individual container where, in general, it remains for the duration of the analytical procedure which is carried out. An advantage of this arrangement is that each discrete sample can be individually labelled, so that confusion between different samples is minimised.

A further type of analyser mixes a sample under investigation with a reagent by injecting them into a chamber from which the reacting mixture is passed to a measurement cell. The mixture is held in this cell for a short time while a measurement, for example a photometric measurement, is carried out.

In a further type of apparatus, samples travel continuously in a carrier stream moving along a narrow flow channel which is designed so that each individual sample retains its integrity with respect to adjacent samples. In one system, slugs of air are used to separate individual samples in the moving stream. In another system, known as flow injection analysis, the carrier medium is the reagent with which the individual samples are to react. A precisely measured sample is injected into the flowing reagent stream at a given point. Injection can take place with a syringe, e.g. through a septum or by means of a rotary valve. In the latter case, the port in the rotary valve constitutes the measuring device; a slight excess of sample is injected through the port which is then rotated to deliver its contents into the flowing reagent stream. The injected slug of sample remains coherent as it passes along the narrow tubing which constitutes the flow channel, although the sample becomes elongated. The sample mixes with reagent by radial diffusion from the boundary layer. Successful operation of this flow injection analysis technique therefore requires that turbulent flow is avoided. This arrangement offers advantages over the system using air-segmented samples, in that it allows more rapid sampling rates without adverse effects on the accuracy of the analytical results obtained. The system does, however, have the disadvantage that it is wasteful of reagent, which in many cases will be an expensive commodity.

U.S. Patent Specification No. 3,489,525 describes an automatic analysis system in which a specimen is mixed with a diluent liquid to form a sample liquid which is then divided into a plurality of sample aliquots each of which is then separately mixed with a different reagent to form a test solution. The test solutions are then individually assayed and recorded. The diluent liquid is obtained from a container by the action of a first peristaltic pump and is delivered to a mixing container, which also receives the sample which is to undergo investigation. The sample arrives in a capillary tube, and is expelled into the mixing container by a blast of air. A plurality of outlets from the mixing container pass through a second peristaltic pump, as do a series of tubes which supply different reagents. Downstream of the second peristaltic pump, tube lines merge so that sample aliquots are mixed with the different reagents for analysis.

U.S. Patent Specification No. 3,690,833 describes an automatic chemical analyser which draws in a fluid sample, advances sample aliquots along processing paths, with a programme of discontinuous motions in which the sample stream is intermittently advanced and then held essentially stationary. The fluid advance/fluid dwell periods are arranged so that the system can simultaneously process a plurality of samples subjected to several different reactions with different incubation times. Only one sample is subjected to assay at any given time, and to achieve the proper sequencing, a complicated fluid directing arrangement is disclosed. The fluid is conveyed along the respective flow channels by proportional pumps, downstream of which reagent and sample flows lines merge to give a series of flow channels in which the reaction between reagent and sample occurs. The complex flow control and fluid directing arrangements necessary for proper operation of this automatic chemical analyser are not required in the present invention.

French Patent Specification No. 2,446,480 describes an analytical system in which a continuously flowing stream of biological samples are transported along a flow channel one after the other separated by segments of rinsing water. A portion of a sample is drawn up into a probe carried on an arm by the action of an aspirating syringe. The arm is displaced, and the sample held within the probe is expelled into a container followed by sufficient distilled water to give the desired dilution. The container which receives the diluted sample is on a turntable which rotates so that the container can occupy one of a series of locations. Rotation is effected, and part of the diluted sample is extracted for analysis, e.g. by flame photometry. The operating sequence of the apparatus is arranged so that delivery of a sample into one container can take place simultaneously with withdrawal for analysis of a further sample for another container. The flow channel leading towards the analysis station will thus contain a succession of segments consisting of sample, air and rinsing water. There is no provision for the introduction of a reagent into that segment of the flow channel which contains a sample for analysis. The apparatus is thus principally concerned with controlled dilution of a succession of samples.

According to one aspect of the present invention there is provided a method of analysis of a

liquid sample which is carried along a flow channel by a carrier liquid, which method comprises simultaneously introducing a predetermined quantity of a given sample and a predetermined quantity of a selected reagent directly into separate flow lines by aspiration from separate containers; bringing the extracted sample and the extracted reagent together into a common flow channel; and causing the sample/reagent mixture to travel along said flow channel to the measurement cell of an analytical instrument, the sample and reagent being aspirated and caused to flow along the flow channel by a peristaltic pump, characterised in that: (1) the sample and reagent are extracted by hollow probes which are connected to the peristaltic pump; and (2) after the predetermined quantities of sample and reagent have been aspirated, the hollow probes are transferred while pump action is momentarily stopped to a container of a carrier liquid, whereafter the pump is re-started, whereby the sample and reagent are caused to travel along said flow channel as a discrete liquid slug interposed in a stream of carrier liquid.

The method of the invention can be used in the sequential analysis of a series of samples. It can operate with a plurality of samples simultaneously present at different positions within the flow channel, or with just a single sample at any one time within the flow channel.

The method of this invention does not require the use of air bubbles to segment the carried liquid. Thus the material present in the flow channel is in the form of a continuous liquid, the carrier liquid having interposed therein discrete liquid slugs of sample/reagent mixture (hereinafter called "active slugs"). Conveniently, the carrier liquid is distilled water; there is no need to use a carrier liquid which is immiscible with the active slug.

The method operates under conditions of laminar flow in the flow channel, and only relatively low pressures are required to pump the material along the flow channel.

The flow channel is preferably constituted by clear piping of internal diameter not greater than 1 mm; commercially available polyethylene or polypropylene tubing has proved to be satisfactory.

Preferably, the sample and reagent are extracted from their respective containers by probes or dip-tubes which are connected to narrow bore tubing which leads to a peristaltic pump. The probes can remain in a source of carrier liquid until an active slug is to be introduced into the flow channel. The probes are then transferred from the source of carrier liquid to the respective containers of sample and reagent.

The peristaltic pump is preferably driven by a stepping motor under control of a microprocessor so that the motor can make precisely controlled angular movements. This in turn effects precise control of the proportions of active slugs and carrier liquid which pass along the flow channel. As well as allowing precise control of the material in the flow channel, the use of a stepping motor controlled by a microprocessor enables the method of the invention to be very flexible, in that the size of successive samples, the gap between successive samples and the time selected for the analytical measurement of samples can all be varied independently.

It is preferred that the quantity of reagent extracted should exceed that of sample; thus when the sample and reagent are brought together, which is preferably at a Y-piece or T-piece made for example, of plastics tubing, the active slug thereby formed ensures excellent mixing of sample with reagent while being very economical in terms of the quantity of reagent which is used.

The pump tube provided for that probe which, in use, extracts reagent can be of a larger diameter than the other pump tube. Thus a given angular rotation of the peristaltic pump will cause the quantity of reagent which is taken up to be larger than that of the sample which is to be investigated.

Generally, the flow channel will include a coil of narrow bore tubing of a length sufficient to give the desired contact time between sample and reagent. The flow channel would also include an analytical station, for example the flow cell of a colorimeter.

According to another aspect of the present invention, there is provided apparatus for the analysis of liquid samples carried along a flow channel by a carrier liquid, which apparatus comprises a first container for the material a sample of which is to be analysed; a second container for a reagent to be admixed with said sample; a third container for a carrier liquid; means for bringing the extracted sample and the extracted reagent together into a common flow channel; a peristaltic pump for effecting aspiration of liquids from the containers and for pumping the liquids along the flow channel; and means for deriving an analytical measurement from material in the flow channel, the apparatus being characterised by a first hollow probe for insertion into either the first container or the third container; a second hollow probe for insertion into either the second container or the third container; a probe control mechanism for controlling the placement of the first and second hollow probes; and a stepping motor connected or connectable to drive the peristaltic pump, the stepping motor being controllable so that it can make precise angular movements, the hollow probes being connected to the peristaltic pump for aspiration of liquid from the containers.

The means for deriving an analytical measurement can be, for example, a spectrophotometer.

Advantageously, the stepping motor is controlled by a microprocessor. The same microprocessor may also be used to control the analytical instrument, e.g. a spectrophotometer, and to process data produced by that instrument.

The apparatus may also include a turntable for receiving and holding samples which are to undergo analysis; the turntable is preferably con-

trolled by an indexing arrangement actuated directly or indirectly by the stepping motor and controlled by the microprocessor.

The method and apparatus of the invention are especially useful in clinical analysis. The method and apparatus may be used to obtain data for instantaneous reactions between sample and reagent; for example, in the measurement of serum calcium levels, the sample is mixed with a reagent consisting of a solution of cresophthalein complexone. A blue colour develops immediately the intensity of which is proportional to the concentration of calcium in the sample. With an instantaneous reaction of this sort, the active slug can be pumped through the flow cell of a colorimeter without stopping, and the maximum signal derived from the photometer represents the calcium concentration of the sample in question.

The method and apparatus may also be used to derive data from samples which undergo a slow reaction with their reagent. Thus in the measurement of serum glucose levels, a sample of the serum under investigation is mixed with the enzyme glucose dehydrogenase. The mixture is incubated, typically at 30°C, and as a result of the reaction the coenzyme nicotinimide adenine dinucleotide is converted into its reduced form which absorbs light in the ultraviolet region of the spectrum. In investigations of this type, the active slug is pumped into the flow cell of the colorimeter; the pump is then stopped and the signal from the colorimeter is observed for a predetermined period, for example 15 seconds. The rate of change of the colorimeter signal in the course of the observation is then proportional to the concentration of glucose in the serum sample.

One embodiment of the apparatus of the invention will now be described, by way of example, with reference to the accompanying drawing which illustrates the apparatus diagrammatically.

The drawing shows a pair of probes 1 and 2 inserted into, respectively, a container S containing a sample which is to be analysed, and a container R which contains a reagent which is to be reacted with the sample S. A probe control mechanism 3 is provided which is operated by a stepping motor 5 through an indexing arrangement 4. The probe control mechanism serves to transfer the probe from sample and reagent containers to a third container C which is a source of inert carrier liquid, for example distilled water. The alternative positioning of the probes in the container C is indicated by the dashed lines 1' and 2'. The sample container S is located on a turntable (not shown) which carries a series of samples which are to be analysed sequentially by the apparatus. The stepping motor 5 is controlled by a microprocessor 6. The apparatus also includes a peristaltic pump 7 the operation of which is effected by steeping motor 5 under control of microprocessor 6. Material within probes 1 and 2 is drawn by the action of peristaltic pump 7 along conduits 8 and 9, respectively (formed by narrow bore plastics tubing) whence they pass through the pump at 8a and 9a, respectively and reach a Y-piece 10, where the two flow streams are combined, via tube portions 8b and 9b, respectively. Downstream of Y-piece 10 there is an elongate channel 11 which leads to the measurement cell 12 of the spectrophotometer. The output 13 from the spectrophotometer is fed to microprocessor 6, and one or more analytical parameters derived from output 13 are displayed on a display unit 14. After passing through the measurement cell 12 of the spectrophotometer, the fluid is passed to waste at 15. The flow channel through the apparatus consists of probes 1 and 2, conduits 8 and 8a, 9 and 9a, 8b and 9b, Y-piece 10, elongate channel 11 and the passage to disposal at 15. Throughout its length, the flow channel can be formed of narrow bore polyethylene tubing. The internal diameter of the tubing is preferably less than 1mm. The parts 8a and 9a are generally known as pump tubes; since the action of peristaltic pump 7 is such that its rollers exert a uniform linear driving action over the two pump tubes, the volume of liquid delivered by a given sweep of the pump rollers is proportional to the internal diameter(s) of the pump tubes. Thus by employing tubes 8a and 9a of different internal diameter, the sample:reagent ratio drawn from containers S and R, respectively, can be varied at will.

The apparatus illustrated diagrammatically in the drawing is operated as follows: at the start of an analysis, the two probes are in the position shown by dashed lines 1' and 2', i.e. they both dip into a source of carrier liquid, e.g. distilled water. Operation of peristaltic pump 7 under these conditions will draw distilled water through the apparatus, this serving as a washing function. Operation of the peristaltic pump 7 is stopped, so that there is no fluid flow through the flow channel of the apparatus. Probe control mechanism 3 is then actuated by stepping motor 5 and indexing arrangement 4 to lift the probes from container C and to insert probe 1 into the sample S, and probe 2 into the reagent R. Microprocessor 6 then actuates stepping motor 5 to operate peristaltic pump 7. The pump makes a predetermined angular movement, thus drawing up a precise volume of sample (e.g. serum) and a precise volume of reagent into the probes 1 and 2 respectively. The pump tube 9a is of a larger internal diameter than the pump tube 8a; this serves to ensure that the volume of reagent drawn up by a given angular movement of the pump 7 is larger than the volume of sample drawn up by the same angular movement of the pump. Operation of the peristaltic pump is then stopped, and probe control mechanism 3 transfers the probes 1 and 2 back to the source of carrier liquid C. Peristaltic pump 7 is then actuated once again, so that the sample and reagent already contained within probes 1 and 2 are drawn through the pump 7, while distilled water from container C is drawn through the flow channel immediately behind the sample and reagent so that the material in the flow channel is a continuous liquid phase. Continued operation of

the pump causes the respective slugs of sample and reagent to come together at the Y-piece 10, where they merge into a single, active slug which travels along the remainder of the flow channel through the apparatus. Obviously, the path lengths and internal diameters of the tube sections 8b and 9b are arranged to ensure that the sample and reagent reach the Y-piece 10 simultaneously. Meanwhile, the turntable holding samples S is rotated so that the next sample to be analysed is in a position to receive the probe 1. After a predetermined time, operation of the peristaltic pump 7 is stopped once more, so that flow of material through the flow channel of the apparatus comes to a halt. Probe control mechanism 3 then transfers the probes to the containers S and R so that the next sample to be analysed can be drawn into the apparatus together with the reagent therefor.

It will be seen that continued operation in the manner described above results in a series of active slugs passing through the flow channel of the apparatus. Depending on the selected mode of operation, there may be a plurality of active slugs present simultaneously in the flow channel each separated by a predetermined column of carrier liquid, e.g. distilled water; alternatively, the apparatus can be controlled so that a new sample is introduced into the flow channel only when the previous sample has passed through the flow channel and has gone to waste.

Each active slug can comprise terminal regions composed almost entirely of pure reagent, with a central region between them in which sample and reagent are intimately mixed. As each active slug passes along the elongate channel 11, reaction between sample and reagent takes place. The elongate channel 11 will be of a length sufficient to ensure complete mixing between sample and reagent. As the active slug reaches the measurement cell 12 of the spectrophotometer, an optical measurement is taken which is fed as output 13 to the microprocessor 6. The output may be displayed directly on display unit 14, or the microprocessor may be used to calculate one or more analytical parameters derived from the optical measurement.

The nature of the sample and that of the reagent involved in any particular analysis will determine which of these two arrangements is adopted.

Similarly, the optical measurement taken by the spectrophotometer may take place with the active slug flowing continuously through the spectrophotometer, or it may take place with the active slug held stationary within measuring cell 12. The first course will be adopted where the reaction between sample and reagent is instantaneous, or where it is complete by the time the active slug reaches the measurement cell 12, and the second course will be adopted where the reaction between sample and reagent is a slow reaction, i.e. one which is still proceeding at the time the active slug reaches measurement cell 12.

The apparatus described above operates at relatively low pressures and under conditions of laminar flow. The material within the flow channel is a continuous liquid — no segmentation by air bubbles or immiscible liquids is necessary in order to preserve the integrity of adjacent active slugs. A high throughput of samples is possible, and furthermore the sampling rate can be varied according to the nature of sample and reagent which are undergoing analysis. The use of microprocessor 6 to operate stepping motor 5 enables great accuracy to be obtained in the volumes of samples and reagent which are drawn up into the apparatus. The volume ratio between sample and reagent is determined by the ratio between the internal diameters of pump tubes 8a and 9a which are in the form of plastics tubing. It is a relatively simple matter to change one or both of the pump tubes in order to alter the desired volume ratio and hence to alter the relative proportions of sample and reagent which are drawn through the apparatus. The microprocessor 6 can be programmed to act on stepping motor 5 so as to adjust the sampling size, the length of the column of carrier liquid provided between adjacent samples, and the hold time of material within measuring cell 12.

The invention will be further illustrated by the following Examples.

Example 1

The apparatus of the invention was used to perform an assay of serum creatinine by the kinetic Jaffé method. This uses the red coloration formed when creatinine reacts with picric acid (2,4,6-trinitrophenol) and sodium hydroxide to estimate the quantity of creatinine present in the sample. A spectrophotometer having a 7-volt lamp as the light source and a 505 nm filter was used to detect the development of the coloration. The pump tube 8a (for the serum sample under investigation) has an internal diameter of 0.76 mm (0.03 inches) while the pump tube 9a (for the picric acid/sodium hydroxide reagent) had an internal diameter of 1.65 mm (0.065 inches). The flow channel 11 consisted of a coiled plastics tube of internal diamter of (0.76 mm (0.03 inches) wound about a thermostatically controlled heater arranged to maintain the liquid within the flow channel at a uniform 25°C. The peristaltic pump 7, when driven, was operated at 75 revolutions per minute. The microprocessor was programmed to operate the pump with a 10 second aspiration period in which sample and reagent were drawn directly into their separate flow lines 1 and 2, respectively, after which the pump was stopped while the probes were transferred to container C which held delonised water as the carrier liquid. The size of the pump tubes together with the 10 second aspiration resulted in the extraction of 15 microlitres of sample from container S and 65 microlitres of reagent from container R. The pump was then operated for a further 3 seconds, which effected the transport of the active slug formed at 10 to the measurement cell 12 of the spectrophotometer. The pump was then halted

for a period of 15 seconds, during which the colour change within cell 12 was monitored. The active slug was then flushed out of the flow line by a further operation of the pump 7 for a period of 6 seconds. Thus the cycle time per sample was 34 seconds. The determination of the creatinine level of the sample was effected by standard colorimetric analysis and the result was obtained at 14.

Example 2

In order to assess the accuracy of the apparatus and method as described in Example 1, the analytical run was repeated with 20 serum samples and the results were recorded. The same samples were then analysed by the same kinetic Jaffé method on a commercially available centrifugal analyzer (a Centrifichem 400 analyser manufactured by Union Carbide Limited) and the results were compared. The two sets of results were to all intents and purposes identical, the correlation coefficient (r) being r = 0.98.

Example 3

The precision of the method as described in Example 1 was assessed by using pre-prepared creatinine solutions as samples. Ten analytical runs were completed with creatinine levels at (a) 128 millimols/litre, (b) 330 millimols/litre and (c) 970 millimols/litre. The coefficient of variation (cV) was calculated for each of the three levels: cV is the standard deviation expressed as a percentage of the mean value, and is also known as relative standard deviation. The results obtained were as follows:

Creatinine level (mmol/l)	cV (%)
128	6.0
330	2.6
970	3.5

While the apparatus has been described in relation to the measurement of an optical parameter using a spectrophotometer, other analytical instruments may be used as well as, or instead of, a spectrophotometer, depending upon the nature of the material being investigated. Thus it may be valuable, in some analyses, to make electrochemical measurements on the material passing through the flow channel, for example by means of a polarograph.

Claims

1. A method of analysis of a liquid sample which is carried along a flow channel by a carrier liquid, which method comprises simultaneously introducing a predetermined quantity of a given sample and a predetermined quantity of a selected reagent directly into separate flow lines by aspiration from separate containers; bringing the extracted sample and the extracted reagent together into a common flow channel; and causing the sample/reagent mixture to travel along said flow channel to the measurement cell of an analytical instrument, the sample and reagent being aspirated and caused to flow along the flow channel by a peristaltic pump, characterised in that: (1) the sample and reagent are extracted by hollow probes which are connected to the peristaltic pump; and (2) after the predetermined quantities of sample and reagent have been aspirated, the hollow probes are transferred while pump action is momentarily stopped to a container of a carrier liquid, whereafter the pump is re-started, whereby the sample and reagent are caused to travel along said flow channel as a discrete liquid slug interposed in a stream of carrier liquid.

2. A method according to claim 1, further characterised in that a common pump is used to draw sample, reagent and carrier liquid into said separate flow lines.

3. A method according to claim 1 or 2, characterised in that said hollow probes are connected to the peristaltic pump by narrow bore tubing.

4. A method according to claim 1, 2 or 3, wherein the peristaltic pump is driven by a stepping motor under the control of a microprocessor.

5. A method according to claim 1, 2, 3 or 4, characterised in that a single discrete sample/reagent slug is caused to pass along the flow channel at any given time.

6. A method according to claim 1, 2, 3 or 4, characterised in that a plurality of sample/reagent slugs are caused to flow along the flow channel simultaneously, each of the slugs being separated by a predetermined column of carrier liquid.

7. A method according to any preceding claim, characterised in that the flow channel is constituted by piping of internal diameter not greater than 1 mm.

8. A method according to any preceding claim, characterised in that the sample and reagent are brought together at a Y-piece or T-piece forming part of the flow channel.

9. A method according to any preceding claim, characterised in that the quantity of reagent drawn into the flow channel is greater than the quantity of sample.

10. A method according to any preceding claim, characterised in that the or each slug of sample/reagent in the flow channel is subjected to spectrophotometric analysis.

11. Apparatus for the analysis of liquid samples carried along a flow channel by a carrier liquid, which apparatus comprises a first container (S) for the material a sample of which is to be analysed; a second container (R) for a reagent to be admixed with said sample; a third container (C) for a carrier liquid; means (10) for bringing the extracted sample and the extracted reagent together into a common flow channel (11); a peristaltic pump (7) for effecting aspiration of liquids from the containers and for pumping the liquids along the flow channel (11); and means (12)

deriving an analytical measurement from material in the flow channel, the apparatus being characterised by a first hollow probe (1) for insertion into either the first container (S) or the third container (C); a second hollow probe (2) for insertion into either the second container (R) or the third container (C); a probe control mechanism (3) for controlling the placement of the first and second hollow probes; and a stepping motor (5) connected or connectable to drive the peristaltic pump (7), the stepping motor being controllable so that it can make precise angular movements, the hollow probes (1, 2) being connected to the peristaltic pump (7) for aspiration of liquids from the containers.

12. Appparatus as claimed in claim 11, further characterised by a microprocessor (6) adapted to control the stepping motor (5).

13. Apparatus as claimed in claim 12, characterised in that the probe control mechanism (3) is operated through an indexing arrangement (4) by the stepping motor (5) under control of the microprocessor (6).

14. Apparatus as claimed in claim 11, 12, or 13, characterised in that the means for deriving an analytical measurement (12) from material in the flow channel is a spectrophotometer.

15. Apparatus as claimed in claim 11, 12, 13 or 14, further characterised by a turntable for receiving and holding samples which are to undergo analysis.

16. Apparatus as claimed in claims 12 and 15, characterised in that the turntable is controlled by an indexing arrangement actuated directly or indirectly by the stepping motor (5) and controlled by the microprocessor (6).

17. Apparatus as claimed in any of claims 11 to 16, characterised in that the flow channel (11) is constituted by narrow bore tubing of internal diameter less than 1 mm.

18. Apparatus as claimed in any of claims 11 to 17, characterised in that the means (10) for bringing the extracted sample and the extracted reagent together into a common flow channel is a Y-piece or a T-piece.

Patentansprüche

1. Verfahren zur Analyse einer entlang eines Strömungskanals mittels einer Trägerflüssigkeit geführten flüssigen Probe, indem gleichzeitig eine vorbestimmte Menge einer gegebenen Probe und eine vorbestimmte Menge eines bestimmten Reagens durch Ansaugen aus getrennten Behältern direkt in getrennte Strömungsleitungen eingeführt und die entnommene Probe und das entnommene Reagens zusammen in einen gemeinsamen Fließkanal eingebracht werden und das Probe/Reagens-Gemisch entlang des Fließkanals zur Meßzelle eines Analysiergerätes geführt wird, wobei die Probe und das Reagens durch eine Schlauchpumpe angesaugt und durch den Fließkanal befördert werden, dadurch gekennzeichnet, daß (1) die Probe und das Reagens mittels mit der Schlauchpumpe verbundener Hohlsonden entnommen und (2) nach dem Ansaugen vorbestimmter Mengen an Probe und Reagens die Hohlsonden, während die Pumpe vorübergehend abgestellt wird, zu einem Behälter mit einer Trägerflüssigkeit übergeführt werden, wonach die Pumpe neuerlich in Gang gesetzt wird, wobei die Probe und das Reagens veranlaßt werden, als für sich allein stehender, in einen Strom einer Trägerflüssigkeit eingesetzter Pfropfen entlang des gennanten Fließkanals zu wandern.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß zur Förderung der Probe, des Reagens und der Trägerflüssigkeit in getrennte Strömungsleitungen eine gemeinsame Pumpe eingesetzt wird.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Hohlsonden durch Rohrleitungen mit kleiner Innenweite mit der Schlauchpumpe verbunden sind.

4. Verfahren nach einem der Ansprüche 1—3, dadurch gekennzeichnet, daß die Schlauchpumpe von einem Schrittmotor unter der Steuerung durch einen Mikroprozessor angetrieben wird.

5. Verfahren nach einem der Ansprüche 1—4, dadurch gekennzeichnet, daß ein einzelner Probe/Reagens-Pfropfen für sich allein zu jedem gegebenen Zeitpunkt durch den Fließkanal geführt wird.

6. Verfahren nach einem der Ansprüche 1—4, dadurch gekennzeichnet, daß eine Vielzahl von Probe/Reagens-Pfropfen gleichzeitig durch den Fließkanal geführt wird, wobei jeder der Pfropfen durch eine vorbestimmte Säule an Trägerflüssigkeit abgesondert ist.

7. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der Fließkanal durch eine Rohrleitung mit einem Innendurchmesser von höchstens 1 mm gebildet ist.

8. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Probe und das Reagens bei einem einen Teil des Fließkanals bildenden Y-Stück oder T-Stuck zusammengeführt werden.

9. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Menge an in den Fließkanal gefördertem Reagens größer ist als die Menge der Probe.

10. Verfahren nach einem der vorhergenden-den Ansprüche, dadurch gekennzeichnet, daß der Pfropfen oder jeder der Pfropfen aus Reagens/Probe im Fließkanal einer spektrophotometrischen Analyse unterworfen wird.

11. Apparat zur Analyse von durch einen Fließkanal mittels einer Trägerflüssigkeit geführten flüssigen Proben, bestehend aus einem ersten Behälter (S) für das Material, von dem eine Probe analysiert werden soll, einem zweiten Behälter (R) für ein mit der genannten Probe zu vermischendes Reagens, einem dritten Behälter (C) für eine Trägerflüssigkeit, Einrichtungen (10), um die entnommene Probe und das entnommene Reagens in einen gemeinsamen Fließkanal (11) zusammen einzubringen, einer Schlauchpumpe (7) zum An-

saugen von Flüssigkeiten aus den Behältern und zum Pumpen der Flüssigkeiten durch den Fließkanal (11), und Einrichtungen (12) zur Vornahme einer analytischen Messung des Materials im Fließkanal, gekennzeichnet durch eine erste Hohlsonde (1) zur Einführung entweder in den ersten Behälter (S) oder in den dritten Behälter (C), eine zweite Hohlsonde (2) zur Einführung entweder in den zweiten Behälter (R) oder in den dritten Behälter (C), einen Sondensteuerungsmechanismus (3) zur Steuerung der Plazierung der ersten und der zweiten Hohlsonde, und einen zum Antrieb der Schlauchpumpe (7) geschalteten oder schaltbaren Schrittmotor (5), der derart steuerbar ist, daß er zur Durchführung präziser Winkelbewegungen befähigt ist, wobei die Hohlsonden (1, 2) zum Ansaugen von Flüssigkeiten aus den Behältern an die Schlauchpumpe (7) angeschlossen sind.

12. Apparat nach Anspruch 11, gekennzeichnet durch einen Mikroprozessor (6) zur Steuerung des Schrittmotors (5).

13. Apparat nach Anspruch 12, dadurch gekennzeichnet, daß der Sondensteuerungsmechanismus (3) über eine Schaltvorrichtung (4) durch den Schrittmotor (5) unter der Steuerung durch den Mikroprozessor (6) betätigt wird.

14. Apparat nach einem der Ansprüche 11—13, dadurch gekennzeichnet, daß die Einrichtungen (12) zur Vornahme einer analytischen Messung des Materials im Fließkanal aus einem Spektrophotometer bestehen.

15. Apparat nach einem der Ansprüche 11—14, gekennzeichnet durch einen Drehtisch für die Aufnahme und Halterung der zu analysierenden Proben.

16. Apparat nach den Ansprüchen 12 und 15, dadurch gekennzeichnet, daß der Drehtisch durch eine direkt oder indirekt durch den Schrittmotor (5) betätigte und durch den Mikroprozessor (6) gesteuerte Schaltvorrichtung gesteuert wird.

17. Apparat nach einem der Ansprüche 11—16, dadurch gekennzeichnet, daß der Fließkanal (11) durch eine Rohrleitung mit enger Innenweite von einem Innendurchmesser von weniger als 1 mm gebildet ist.

18. Apparat nach einem der Ansprüche 11—17, dadurch gekennzeichnet, daß die Einrichtungen (10) zum gemeinsamen Einbringen der entnommenen Probe und des entnommenen Reagens in einen gemeinsamen Fließkanal durch ein Y-Stück oder eine T-Stück gebildet sind.

Revendications

1. Procéde d'analyse d'un échantillon de liquide qui est entraîné le long d'un conduit d'écoulement par un liquid entraîneur, ce procédé consistant à introduire simultanément une quantité prédéterminée d'un échantillon donné et une quantité prédéterminée d'un réactif choisi, directement dans de tuyaux d'écoulement séparés par aspiration depuis des récipients séparés; à réunir l'échantillon extrait et le réactif extrait dans un conduit d'écoulement commun; et à faire en sorte que le mélange échantillon/réactif se rende en suivant le conduit d'écoulement, à la cellule de mesure d'un instrument analytique, l'échantillon et le réactif étant aspirés et amenés à s'écouler le long du conduit d'ecoulement par une pompe péristaltique, caractérisé en ce que: (1) on extrait l'échantillon et le réactif au moyen de sondes creuses qui sont reliées à la pompe péristaltique, et (2) après que les quantités prédéterminées d'échantillon et de réactif aient été aspirées, on transfère les sondes creuses, pendant que l'action de la pompe est momentanément arrêtée, à un récipient de liquide entraîneur, après quoi on fait redémarrer la pompe, de sorte que l'échantillon et le réactif soient amenés à se déplacer le long du conduit d'écoulement sous la forme d'un bouchon liquide distinct interposé dans un courant de liquide entraîneur.

2. Procédé selon la revendication 1, caractérisé en outre, en ce que l'on utilise une pompe commune pour aspirer l'échantillon, le réactif et le liquide entraîneur dans les tuyaux d'écoulement séparés.

3. Procédé selon la revendication 1 ou 2, caractérisé en ce que les sondes creuses sont reliées à la pompe péristaltique par un tube à alésage étroit.

4. Procédé selon la revendication 1, 2 ou 3, dans lequel la pompe péristaltique est entraînée par un moteur pas-à-pas sous la commande d'un microprocesseur.

5. Procédé selon la revendication 1, 2, 3 ou 4, caractérisé en ce que l'on fait passer un seul bouchon discret échantillon/réactif le long du conduit d'écoulement à un moment donné quelconque.

6. Procédé selon la revendication 1, 2, 3 ou 4, caractérisé en ce que l'on fait s'écouler simultanément le long du conduit d'écoulement plusieurs bouchons échantillons/réactif, chacun des bouchons étant séparé par une colonne prédéterminée de liquide entraîneur.

7. Procédé selon l'une quelconque des revendications précèdentes, caractérisé en ce que le conduit d'écoulement est constitué par une tuyauterie d'un diamètre non supérieur à 1 mm.

8. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que l'on réunit l'échantillon et le réactif à l'endroit d'une pièce en Y ou d'une pièce en T faisant partie du conduit d'écoulement.

9. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que la quantité de réactif aspiré dans le conduit d'écoulement est plus grande que la quantité d'échantillon.

10. Procédé selon l'une quelconque des revendications précédentes, caractérisé en ce que l'on soumet le bouchon ou chaque bouchon échantillon/réactif dans le conduit d'écoulement à une analyse spectrophotométrique.

11. Appareil pour l'analyse d'échantillons liquides entraînés le long d'un conduit d'écoulement par un liquide entraîneur, cet appareil comprenant un premier récipient (S) pour la matière

dont il s'agit d'analyser un échantillon; un deuxième récipient (R) pour un réactif à mélanger à cet échantillon; un troième récipient (C) pour un liquide entraîneur; des moyens (10) pour réunir l'échantillon extrait et le réactif extrait dans un conduit d'écoulement commun (11); une pompe péristaltique (7) pour effectuer l'aspiration de liquides depuis les récipients et pour pomper les liquides le long du conduit d'écoulement (11); et des moyens (12) pour effectuer une mesure analytique sur la matière se trouvant dans le conduit d'écoulement, l'appareil étant caractérisé par une première sonde creuse (1) destinée à être insérée soit dans le premier récipient (S) soit dans le troiseme reciplent (C); une deuxieme sonde creuse (2) destinée à être insérée soit dans le deuxième récipient (R) soit dans le troisième récipient (C); un mécanisme de commande de sondes (3) pour commander la mise en place des première et deuxième sondes creuses; et un moteur pas-à-pas (5) relié ou pouvant être relié de manière à entraîner la pompe péristaltique (7), le moteur pas-à-pas pouvant être commandé de façon qu'il puisse faire des mouvements angulaires précis, les sondes creuses (1, 2) étant reliées à la pompe péristaltique (7) pour l'aspiration de liquides depuis les récipients.

12. Appareil selon la revendication 11, caractérisé, en outre, par un microprocesseur (6) conçu pour commander le moteur pas-à-pas (5).

13. Appareil selon la revendication 12, caractérisé en ce que le mécanisme de commande de sondes (3) est actionné, par l'intermédiaire d'un dispositif d'avancement (4), par le moteur pas-à-pas (5) sous la commande du microprocesseur (6).

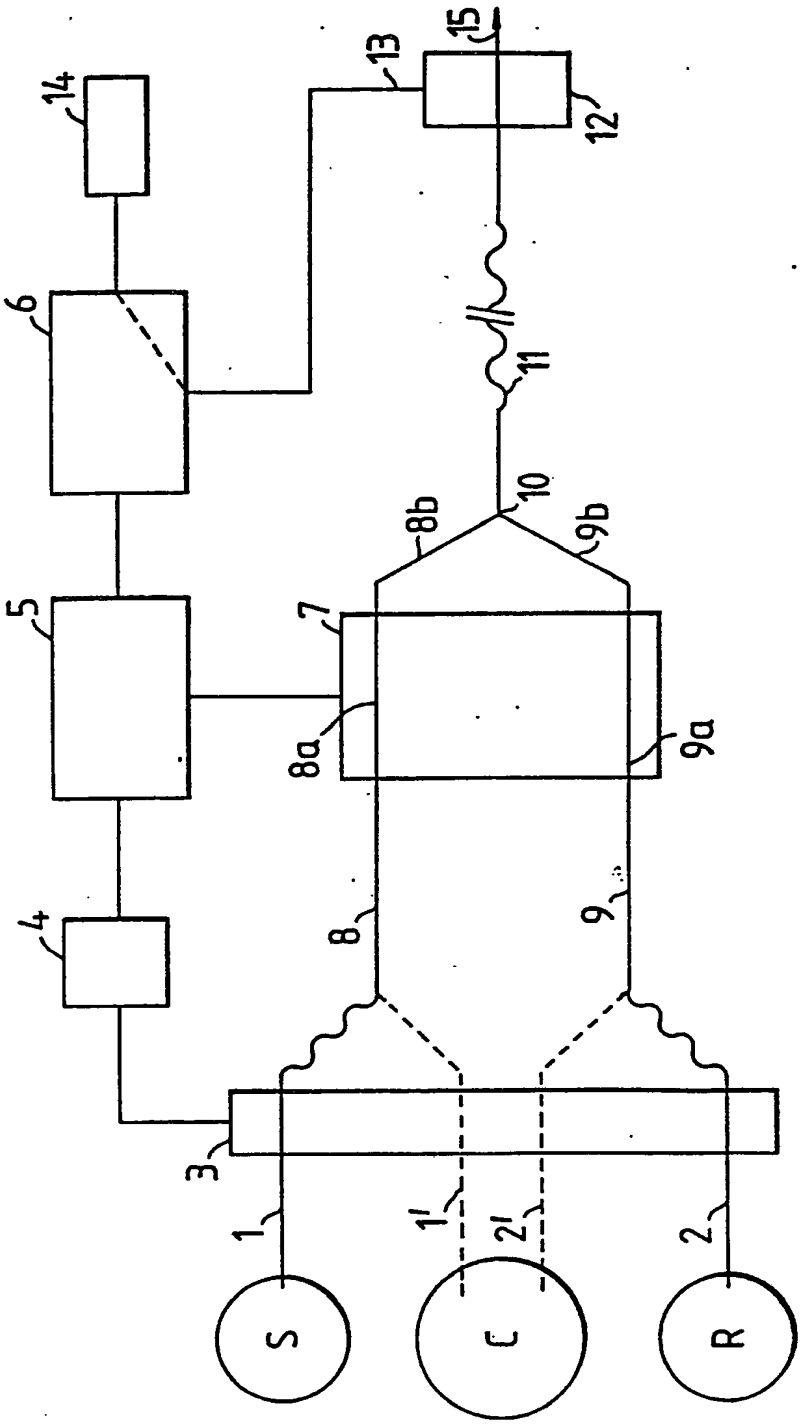
14. Appareil selon la revendication 11, 12 ou 13, caractérisé en ce que le moyen servant à effectuer une mesure analytique (12) sur une matière se trouvant dans le conduit d'écoulement est un spectrophotomètre.

15. Appareil selon la revendication 11, 12, 13 ou 14, caractérisé, en outre, par un plateau tournant destiné à recevoir et à porter des échantillons qui doivent subir l'analyse.

16. Appareil selon les revendications 12 et 15, caractérisé en ce que le plateau tournant est commandé par un dispositif d'avancement actionné directement ou indirectement par le moteur pas-à-pas (5) et commandé par le microprocesseur (6).

17. Appareil selon l'une quelconque des revendications 11 à 16, caractérisé ce que le conduit d'écoulement (11) est constitué par un tube à alésage étroit de diamètre intérieur inférieur à 1 mm.

18. Appareil selon l'une quelconque des revendications 11 à 17, caractérisé en ce que le moyen (10) servant à réunir l'échantillon extrait et le réactif extrait dans un conduit d'écoulement commun est une pièce en Y ou une pièce en T.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